



International Space Station Mars Analog Update

Brief to NASA Advisory Council – August 2, 2011
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◆ Background

- Relationship to NASA 2010 Authorization Act
- Capability Driven Exploration
- Common Capabilities Identified for Exploration
- Mars Design Reference Architecture
- Exploration Mission Risks

◆ Analogs and risk reduction

◆ Why ISS as a Mars Analog?

◆ ISS as an Exploration Test Bed - Objectives

◆ Exploration Capability Phased Development Strategy

◆ Potential Exploration Candidates for ISS Testing Roadmap

◆ International Space Station Test bed for Analog Research (ISTAR)

◆ 4 Phased Approach for ISS as Mars or NEA Test bed

◆ ISS Exploration Testing Flow

◆ Exploration mission plans for Summer 2012

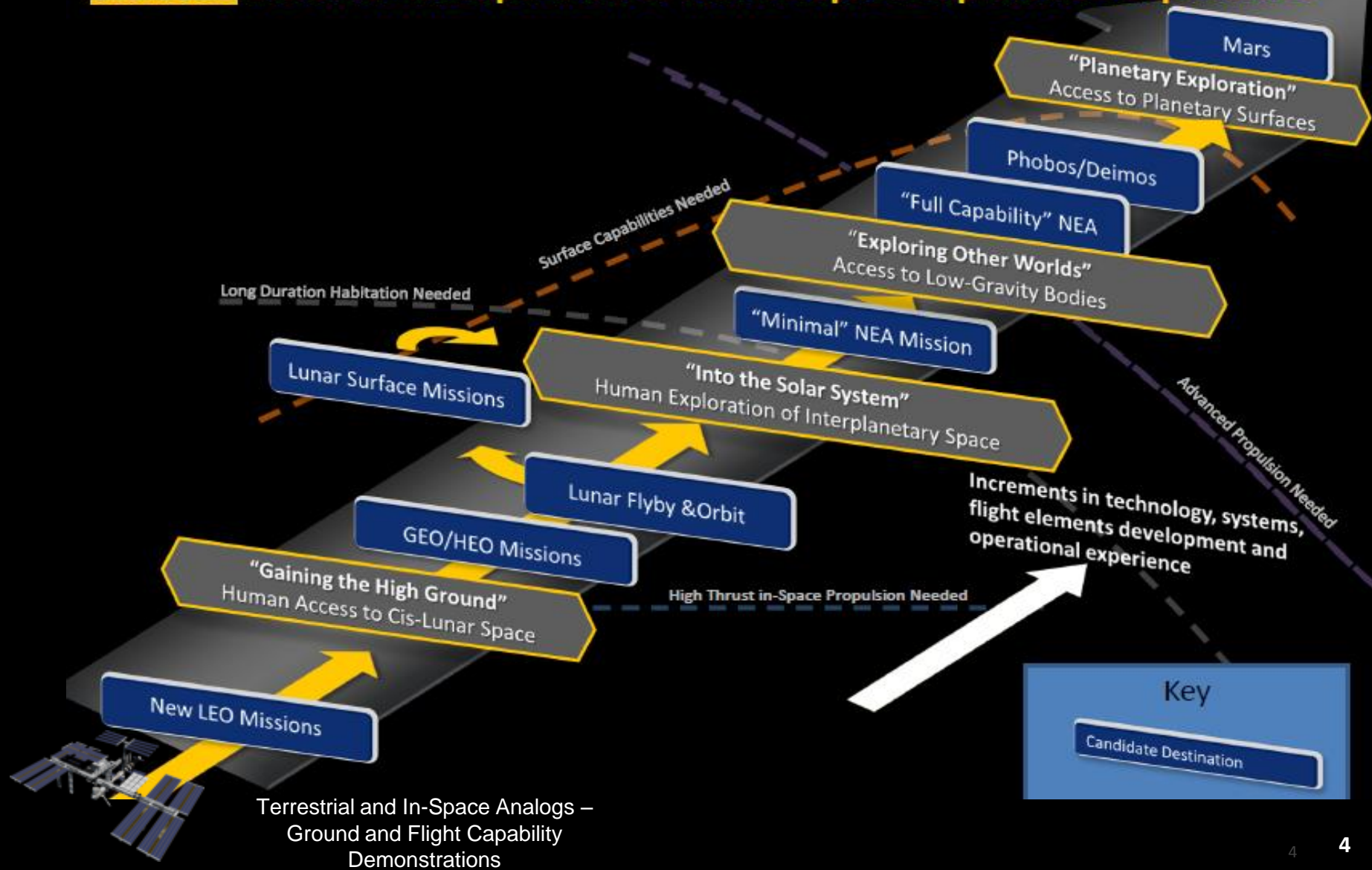
◆ Future Plans

- **NASA Authorization Act of 2010 “Sec 202: HSF and Exploration Goals and Objectives”**
 - **Long term goal – *To expand permanent human presence beyond LEO and so where practical, in a manner involving international partners***
 - **Key objectives: (as related to ISS as an analog for exploration)**
 - ***Sustain the capability for long-duration presence in LEO***
 - ***Determine if humans can live in an extended manner in space with decreasing reliance on Earth, starting with utilization of LEO infrastructure***
- **NASA established the Human Exploration Framework Team in 2010 to develop insights for future human exploration missions with cognizance on the systems requirements and technology drivers required for mission success**
 - **Provides the impetus of the “capability driven framework”**
- **The results of these ongoing efforts are utilized in identifying technology investments and mission planning for across the agency**

Capability Driven Exploration



Notional Incremental Expansion of Human Space Exploration Capabilities



[illegible]

Ground Operations Commercial Cargo/Crew SLS MPCV Robotic Systems SEV EVA Systems CPS DSH Advanced Propulsion Destination Systems Mission Operations

Cross Cutting Systems														Light Weight Long-Life Universal Docking System
Small Payload Return	Robotic Free Flyer inspection	Satellite Servicing Robot	Standardized Energy Storage	Suit Port	ECLSS	Logistics to Living	Prop. Mgt and Storage	Power Module	Modular Solar Arrays	ISRU	Radiation Protection	Comm/Nav		
Personal Space Mobility System	Robotic Assistant	EP Thrusters	Prop from Waste Gasses	EVA Suit	EVA Suit Exoskeleton	Asteroid Anchoring Tools	Self-Healing Systems	Thermo-electric Generation	Modeling and Simulation		Autonomous Ops	Surface Stairs / Ramp System		

Human Exploration Specific Technologies

Mars Design Reference Architecture

◆ Based on “Human Exploration of Mars, DRA 5.0” NASA-SP-2009-566, July 2009.

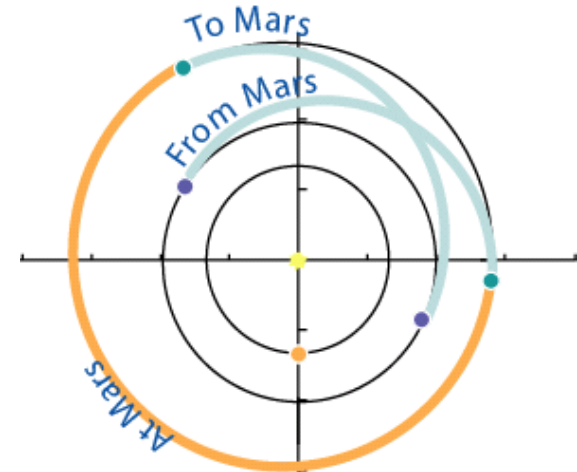
- Transition to Mars of ~180 days [max of 210 days]
- Stay of up to 18 months on the surface
- Return to earth ~180 days [max of 210 days] transition
- Early launch of cargo and habitat prior to human launch

◆ Long-surface Stay + Forward Deployment

- Mars mission elements pre-deployed to Mars prior to crew departure from Earth
 - Surface habitat and surface exploration gear
 - Mars ascent vehicle
- Conjunction class missions (long-stay) with fast inter-planetary transits
- Successive missions provide functional overlap of mission assets

◆ Benefits from this DRA

- Mars DRA spans the spectrum of possible HSF exploration missions (NEA, Moon, or Mars)
- Identifies the core risks for exploration



Exploration Mission Risks

Reference: Human Spaceflight Architecture Team (HAT)



ID	Exploration Mission RISK	ISS Demo Candidate (DRAFT)
M-EDL	EDL of large Mars payloads	
E-EDL	Earth re-entry at high velocities	
LV	Launch vehicle failures	
Lndr	Lander propulsion systems failure	
CSM	Long duration low/zero boiloff cryo-storage and management	X
CFT	In-space cryogenic fluid transfer	X
ISP	In-space propulsion failures	X
A-ISP	Reliability verification of advanced in-space propulsion	
Env	Environmental risks: radiation, MMOD, dust, electromagnetic	X
Dock	Docking/assembly failures	X
Sys	Systems failures: ECLSS, power, avionics, thermal	X
EVA	EVA system/suit failure	X
Comm	Operations under time delayed communication	X
Aut	Autonomous crew/vehicle operation	X
Health	Crew health: behavioral, health care/remote medical, micro-gravity	X
SW	Software failure	X
Hum	Human error	X
ISRU	ISRU equipment failure: propellant, consumables	X

Why ISS as a Mars Analog?



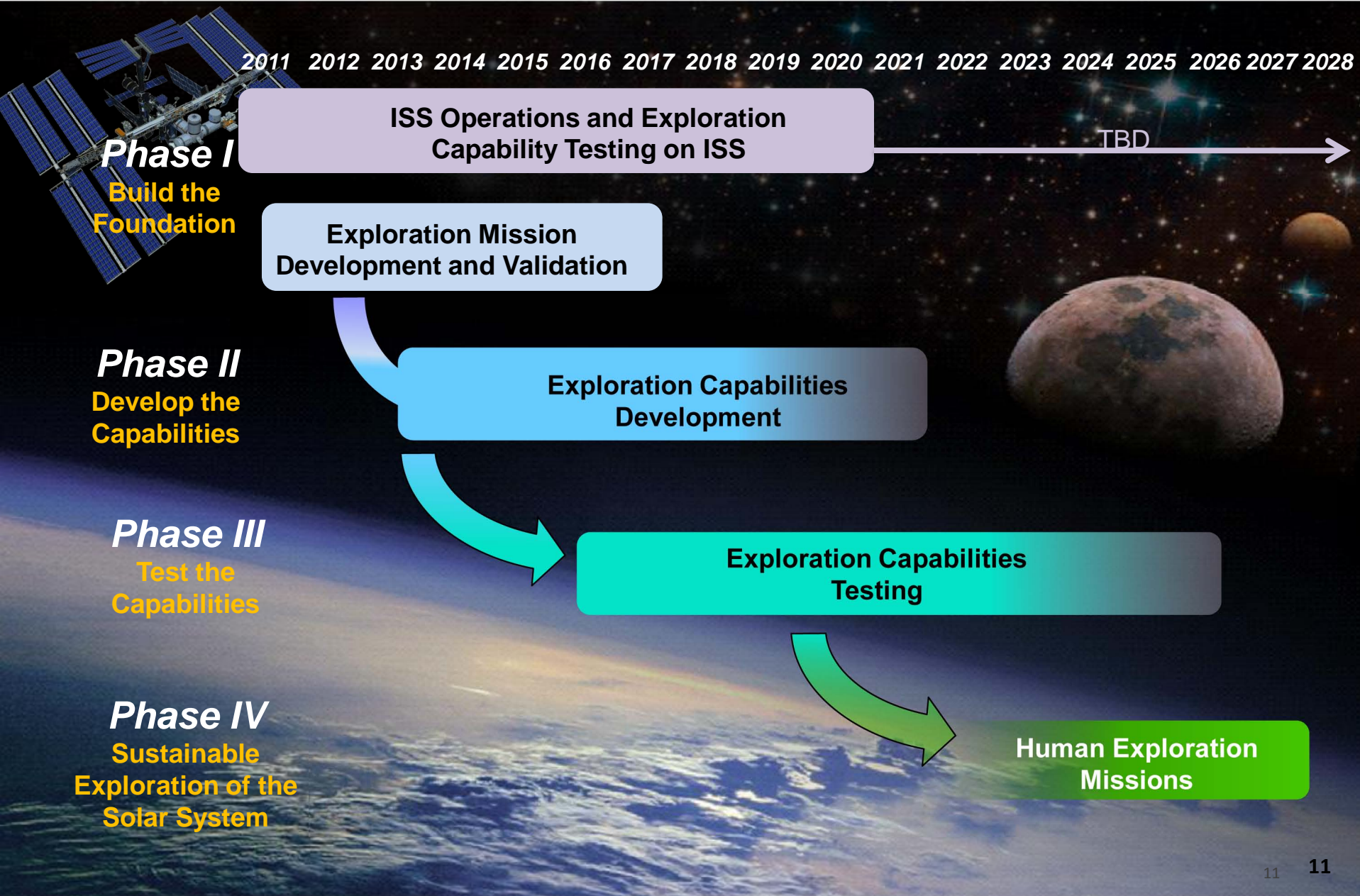
- The ISS provides crew durations that mimic Mars transit phase (approx 6 mos)
- The ISS continuous operations in micro-g provides systems durations that span the Mars mission – validates system performance requirements
- Long duration microgravity environment – pressurized and un-pressurized payloads
- Science Laboratories from four international space agencies – US, Europe, Japan, and Russia
- Life support, power, data, and facilities for 6 crew (subjects and operators)
- Ground control and on-orbit support for 24/7 operations

ISS as an Exploration Test Bed - Objectives



- ◆ Evaluate new exploration technologies as they become available
- ◆ Advance preparations for crew autonomous operations for Mars or NEA exploration
- ◆ Exercise ground elements training and technology development
- ◆ *Long Term Goal*
 -Conduct long duration Mars Transit and Landing Transition simulations using technology and operational tools & concepts developed and tested during previous On-Orbit and Earth-based Analogs

Exploration Capability Phased Development Strategy



Potential Exploration Candidates for ISS Testing Roadmap



2012

2013

2014

2015

2016

2017

2018

2019

R2 0-G Mobility System
IVA/EVA

RCS Sled / Manipulators

Robotic Free Flyer
Inspector

Robotic Free Flyer
Satellite Servicing

Super Safer Personal
Mobility System

Adv. Suits
and PLSS

Exploration Test
Vehicle w/Suit Port

SEV w/Adv
Suits

SEV ECLSS sub-system
Test

Exploration Comm Loop

Modular Power
Systems (Batteries, PV)

Advanced Logistics and
Waste Mgt.

ISS/DSH Reliable
ECLSS

Hab. Vol w/Robust ECLSS, Rad
Protection, Adv Docking System

Exploration Optical
Comm Loop

Radiation Mitigation
Testing

ISS Airlock to Test
Exploration
Atmosphere and
EVA ops

CPS Protoflight Test

Human Health

Time Delayed
Mission Ops

Autonomous Mission
Ops

Robotic
Systems

EVA
Systems

SEV

DSH

CPS

Mission
Operations
12

International Space Station Test bed for Analog Research (ISTAR)






- ◆ **ISTAR is a joint collaboration project between NASA's Exploration and International Space Station (ISS) Programs**
 - An ISTAR Integrated Product Team (IPT) has been established
 - NASA Multi-center team including Exploration Systems, Exploration Analogs, Flight Crew, Human Research Program, Mission Operations, ISS Utilization, Engineering
 - Defines and ranks Exploration Development Test Objectives (xDTOs)
- ◆ **ISTAR xDTO categories established to mitigate Key Exploration Risks and answer Architectural Questions**
 - Human Research including Behavioral, Medical, and Performance
 - Autonomous Operations
 - Mission Planning & Execution
 - Exploration Technology Demonstration
- ◆ **ISTAR collaborates with NASA Earth-based analogs**
 - DRATS - Desert Research and Technology Studies
 - NEEMO - NASA Extreme Environment Mission Operations
 - PLRP – Pavillion Lake Research Project
 - Space Station Training Facility (SSTF), Neutral Buoyancy Lab (NBL), etc.

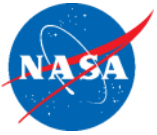
4 Phased Approach for ISS as Mars or NEA Testbed



Phase	Major features of plan
A Eval ISS capabilities [2011]	ISTAR will use planned ISS operations and activities for Mars and NEA Risk Abatement. Operational, experimental protocols to protect safety, health, efficiency of ISS crewmembers are evaluated for their applicability to Mars (and NEA) missions. Other analog environments are reviewed to ensure maximum utilization & lessons learned prior to manifesting on ISS.
B Short-period simulations & experiment packages [2012-2013]	An initial Mars transit mission simulation is planned for Summer 2012. This simulation will include evaluation of countermeasures for communications delays , medical and behavioral experiments, technology / process improvement research and human/robot interactions. Crew procedures and MCC oversight will be modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Emphasis on crew and ground behavioral and performance measures, autonomy. Architectural risk mitigation limited due to hardware development, processing and manifesting timelines.
C Longer-period simulations & experiment packages [2014-2016]	Longer periods of autonomy will be simulated. Comm delays will be used to simulate those that will be encountered in Mars transitions. Crew procedures and MCC oversight continue to be modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Other technology and process improvement research experiments will also be conducted. Increasing emphasis on DTOs for hardware, subsystems, food systems, logistics, etc. May include IV and EV experiments. Post-landing multi-day activities will be conducted.
D 6 month mission and crew [2016-2020]	Transits to Mars (and NEAs) will be simulated as rigorously as feasible in low Earth orbit with existing infrastructure. Progressively increasing communications delays may be introduced, reaching the maximum delay after 6 months to mimic Mars proximity. On-board science operations to be compatible with Mars-like mission parameters. Emphasis gradually shifting to efficacy of countermeasures for behavioral, health and performance. Subsystem level hardware analysis, e.g. ECLSS, EPS, etc. Post-landing exploration mission analogs will be expanded.

<div> <div>ISTAR 1 xDTOs</div> <div>Planned for ISS Increment 31-32 (Mar – Sep 2012)</div> </div>			Risk Reduction				
ISTAR ID	Proposer	xDTO Name	Aut Ops	EVA	Sys Fail	Env	Crew Health
Description of Candidate							
<div> <div>JSC- HEDS-001</div> <div>HEDS</div> <div>Communications Delay Countermeasures</div> </div> <p>Evaluate countermeasures for voice communication delays. Identify what types of tasks are most affected by a comm delay and which countermeasures provide the best results. Participants include flight crew and ground crew. Survey the flight and ground crews in flight for lessons learned that can be incorporated for additional testing later in the increment.</p> <div>   </div>			X				
<div> <div>JSC-011</div> <div>JSC/SF2</div> <div>Active Shielding Proof of Concept</div> </div> <p>Radiation Shielding: Gather real-time in-orbit data on power consumption and particle trajectories to assess the feasibility of implementing a large-scale magnetic field to shield crew. No new hardware required. Will utilize Alpha Magnetic Spectrometer (AMS) measurements. [Requires PI approval]</p>						X	X
<div> <div>JSC-017</div> <div>ARC</div> <div>SPHERES Free Flyer Simulated EVA Inspection</div> </div> <p>The Human Exploration Telerobotics project is working to upgrade the capabilities of the Synchronized Position Hold Engage Reorient Experimental Satellites (SPHERES) to enable interactive control (with crew or from the ground) and utilize an integrated vision system to inspect small IVA features to simulate EVA inspections for MMOD damage. Demonstrate how robotic inspection tasks can reduce the time required for inspections that are normally conducted by the crew.</p>			X	X			
<div> <div>JSC-091</div> <div>JSC/ER4</div> <div>Robonaut 2 Simulated EVA Routine and Emergency Operations</div> </div> <p>Robonaut 2 (R2) brings an unprecedented level of robotics dexterity to ISS. Initially, R2 will earn its stripes in the IVA environment and a fixed base progressing over time toward mobility and EVA. In preparation for transitioning to an EVA version of R2, it is proposed to conduct EVA-like tasks using the IVA R2.</p> <div>  </div>			X	X			

ISTAR Assumptions



- ◆ **Mission priorities:**
 - Support Exploration risk reduction and strategy needs
 - No Mars Mission related analog test should place the ISS vehicle or crew at risk
 - No impacts to current ISS protocols near term
- ◆ **Maximize number of crew members involved to evaluate team FTO's**
- ◆ **Use current Soyuz crew rotation scheme**
- ◆ **Preserve or accommodate original ISS VV schedule**
- ◆ **Assume an ISS flight control team for comm, timelines, systems experts**
- ◆ **Develop rules for simulation breakouts for ISS nominal events and anomalies [while maximizing continuous sim time]**

ISTAR Comm Delay Status



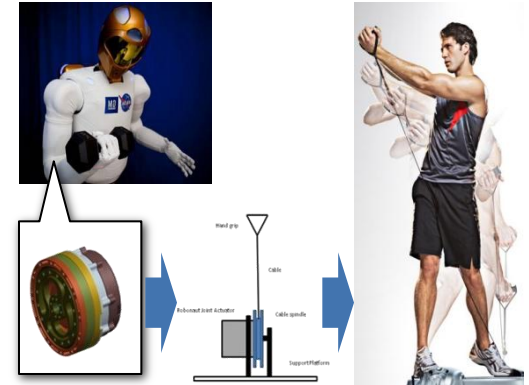
- ◆ **Human Research Program (HRP) is developing a comm delay research investigation JSC-HRP-076 [Voice Comm Delay] to fly on Incr 35/36.**
- ◆ **In preparation for HRP comm delay research, the ISTAR team has prepared a proposal for Incr 31/32 and 33/34 to evaluate operational countermeasures for the crew and ground to use when voice comm is not available [video clips, text, voice sound clips (eg: MP3 files)]**
- ◆ **Objectives for Incr 31/32**
 - **Evaluate comm-delay countermeasures for use in long duration zero-g missions**
 - **Begin training the FCT for more autonomous crew operations**



Increments 33 & 34 RP Development Planning

Example – Page 1a (Investigation Summary Overview)

Miniature Exercise Device (MED)



RESEARCH OBJECTIVES:

- The Miniature Exercise Device will demonstrate key motion system technology required to reduce the volume and weight of countermeasure equipment that will be needed for long term space flight.
- The goal is to develop countermeasure systems that are small and an order of magnitude lighter than existing systems.

OPERATIONS:

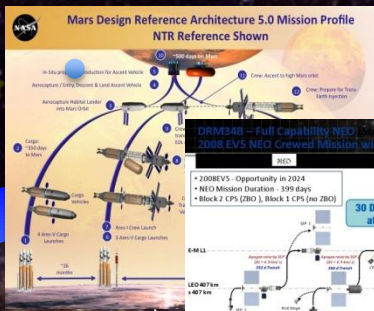
- The ISS Crew will train for installation and operations of the MED. This training is expected to be about 2 to 4 hours.
- The crew will install the MED device on the Advanced Resistive Exercise Device (ARED).
- The crew will use the MED at various load levels and modes of operation. Data will be recorded by the instrumentation on the MED and sent to the ground for evaluation.
- The crew will report observations on the performance of MED to the ground team.
- The ground team will analyze the data and determine control parameter adjustments as needed to tune the MED
- After making changes to the control parameters the crew will use the MED at various load levels and modes of operation.
- This cycle is repeated for a total of not less than 3 sessions.

- ◆ **Continue near term ISTAR efforts to mature exploration capabilities via DTO's on ISS**
 - DTO's are being proposed for future Increments

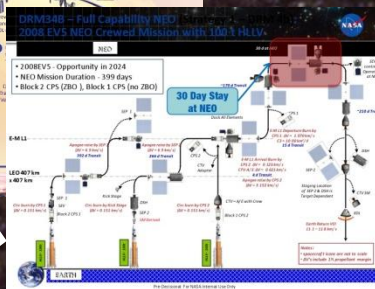
- ◆ **More complex system level candidate proposals, from Candidate Roadmap, are being developed jointly between Exploration and ISS teams**
 - White papers are being developed for EVA, ECLSS, Communication and Exploration Test Module (ECD = Fall 2011)

ISTAR

International Space Station Test Bed for Analog Research



Design Reference Missions and Architectures



Human & Architectural Risks

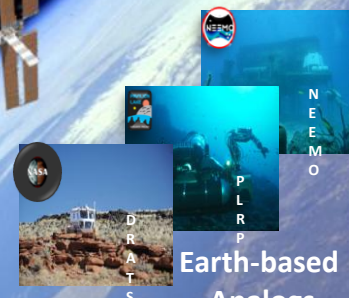
ID	RISK – Human Spaceflight Architecture Team (HAT)
M-EDL	EDL of large Mars payloads
E-EDL	EDL of large Mars payloads
LV	EDL of large Mars payloads
Lndr	EDL of large Mars payloads
CSM	EDL of large Mars payloads
CFT	EDL of large Mars payloads
ISP	EDL of large Mars payloads
A-ISP	EDL of large Mars payloads
Env	EDL of large Mars payloads
Dock	EDL of large Mars payloads
Sys	EDL of large Mars payloads
EVA	EDL of large Mars payloads
Comm	EDL of large Mars payloads
Aut	EDL of large Mars payloads
Health	EDL of large Mars payloads
SW	EDL of large Mars payloads
Hum	EDL of large Mars payloads
ISRU	EDL of large Mars payloads

“Using ISS as an analog test platform to develop and demonstrate new technologies and operational concepts. ISTAR xDTOs mitigate the risks and challenges facing astronauts on long distance voyages to asteroids, planet Mars and perhaps destinations even further from Earth.”

ISTAR Process

- xDTO Solicitation
- xDTO Screening
- Increment Planning
- xDTO Candidates Selection
- Collaboration with Earth based Analogs

**Coming to NASA Summer
2012**



**Earth-based
Analog**